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Flexural Analysis of Concrete Specimens with Substantial Substitution of Cement by Marble Dust and Scrap Rubber as Fibre

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Abstract

Concrete is a crucial material in building and construction. Concrete is becoming more and more in demand every day. Concrete's essential ingredients are running out, therefore we need to find replacements. In addition to providing the necessary strength to the concrete, the replacement materials should also have the properties of the genuine components used in concrete. Typically, compression is where concrete shines, whereas tension and shear are where it falters. This research is being done to find out how fibre-reinforced concrete behaves. The qualities, such as compressive, flexural, and split tensile strength, are examined by incorporating rubber tyres into the concrete at a 2% ratio. Two percent fibre was shown to be the sweet spot. Since ancient times, architects have frequently chosen to work with marble. The goal of this research was to find the best way to incorporate waste marble dust into concrete without sacrificing strength by using the recommended quantity of rubber tyre fibres (2%). The effects of partial replacement at different percentages, such as 0%, 10%, and 20%, on concrete characteristics were studied.

Keywords: Rubber tyre, waste marble dust, concrete, compressive strength, flexural strength

INTRODUCTION

General

There is no denying concrete's versatility as a building material in the context of today's advanced civil infrastructures. Compression is where concrete shines, as opposed to tension or shear where it falls short [1]. Instead of further developing concrete in the hopes of increasing its tensile and shear strengths and improving its ductility, fibre was introduced as a replacement. Researching the thermochemical behaviour of concrete reinforced with macro (structural) synthetic fibre [2] was, thus, the focus of this work. Experiments were done in order to establish these characteristics.

Fibre-Reinforced Concrete

Normal concrete can benefit from fibre reinforcing, although it is most commonly employed with lightweight concrete. Floors and pavements above ground are the most popular applications for fibre-reinforced normal concrete, but it may also be used for other structural components including beams, pillars [3], and foundations when combined with hand-tied rebar [4].

By adding fibres to the matrix of concrete, the main goals are to increase its apparent ductility and its ability to absorb energy [5], as well as to make it less likely to break and to control cracks. It also helps the substance stay together and keep its shape.

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Historical Perspective

Reinforcement by the use of fibres is not a novel idea. Fibrous reinforcement has been in use for a very long period. Traditionally, mudbricks and mortar were made with horsehair. Fibre-reinforced concrete, which often includes asbestos fibres, has been a topic of discussion since the advent of the concept of composite materials in the 1950s. After it was realized that asbestos posed serious health dangers [6], it became necessary to develop a new material to utilize in lieu of asbestos in concrete and other construction products. Steel, glass (high-performance fibre reinforced concrete) [7], and synthetic fibres like polypropylene fibre began to be utilized in concrete by the 1960s, and the hunt for improved fibre-reinforced concretes continues to this day.

Effect of Fibres in Concrete

Plastic shrinkage cracking and drying shrinkage cracking are both mitigated by the inclusion of fibres in concrete. And they stop water from leaking through the concrete by decreasing its permeability. Increased resistance to impact, abrasion, and shattering is produced by using specific kinds of fibres in concrete [8]. Fibres cannot be used in place of moment resisting or structural steel reinforcement in concrete since they do not boost the material's flexural strength. While certain fibres provide strength to concrete, others weaken it.

The volume fraction of a composite material (concrete plus fibres) is the unit of measurement for the quantity of fibres added to a concrete mix (Vf). Vf is normally between 0.1% and 3.0%. Fiber length (l) is divided by fibre diameter (d) to get the aspect ratio (l/d). When calculating aspect ratios for non-circular fibres, equivalent diameter is typically used. If the elastic modulus of the fibres is greater than that of the matrix, then the tensile strength of the material will be increased (the concrete or mortar binder). As the fibre aspect ratio increases, the flexural strength and toughness of the matrix frequently begin to segment. Long fibres, on the other hand, tend to "ball" up in the mixture [9, 10], which makes it difficult to work with them.

Recent studies have shown that adding fibres to concrete does not improve the material's resistance to impact. This discovery is significant because it challenges the conventional wisdom that fibres make concrete more rigid.

When compared to longer fibres, macro fibres have a higher resistance to impact. Concrete linings of 18 and 32 metres in length were reinforced with 1 kg/m^3 of polypropylene fibres and used in the construction of the High Speed 1 tunnel [11, 12].

Firer-Reinforced Concrete Developments

The newly developed fibre-reinforced concrete known as engineered cementation composite (ECC) is 40% lighter than concrete while also being 500 times more crack-resistant. ECC is more flexible than fibre-reinforced concrete or regular concrete because it does not harden when stretched beyond a few percent [13, 14]. Additionally, ECC uses a unique method to crack codes. Even after being stretched to tensile stresses of several percent and loaded beyond its elastic limit, the ECC crack width does not exceed 100 metres.

Recent research has shown that including fibres in high-performance fiber-reinforced concrete used in bridge decks increases the deck's strength and significantly decreases the likelihood of cracking. Despite having a greater degree of shrinkage, the fibre-reinforced concrete showed fewer signs of cracking than the control. Fibre determines durability.

High-performance fibre-reinforced concrete, which is concrete that is held together with natural fibers, works well. The cellulose fibres that are used to make high-performance fibre-reinforced concrete come from slash pine trees whose genes have been changed. This wood has thicker and longer cellulose fibres than other woods.

The idea of recycling carpet fibres into concrete has been looked into as a more environmentally friendly alternative to traditional ways of dealing with trash. A carpet is made up of three main parts: face fibers [15], a backing (usually a fabric made from polyolefin tape yarns), and styrene-butadiene latex rubber (SBR) with $CaCO_3$ filler. It is possible to strengthen concrete with steel and polyolefin fibres.

Marble Dust

Marble is a kind of metamorphic rock formed when limestone undergoes a metamorphic metamorphosis. The beauty and brilliance of marble comes from its inherent purity. If all of the limestone's constituents are calcite (100% $CaCO_3$), the stone will appear white. Marble has many practical and aesthetic applications. Because of its resilience and refined aesthetic, marble is in high demand. Marbles are crystalline rocks with a chemical composition dominated by the minerals calcite, dolomite, or serpentine. All the other mineral components are unique to their respective environments of formation. Chemical impurities in marble include silicon dioxide, limonite, iron oxide, manganese dioxide, hydrogen sulphide, and iron pyrite. Major mineral impurities include quartz, muscovite, tremolite, actinolite, microline, talc, garnet, osterite, and biotite. Magnesium, phosphate, lead, zinc, alkalis, and sulphides are the principal contaminants in raw limestone (for cement) that might impact the qualities of final cement. When cutting, a great deal of powder is produced. As a result, the quantity of waste marble, representing 20% of the entire quantity of marble mined, has grown to the multi-million-ton range. Putting this trash out in the open might be harmful to the ecosystem. A lighter environmental footprint is possible because of concrete technological advancements that cut down on the use of natural resources and energy sources. Marble dust has a significant effect on both individuals and the environment due to the current high production rates at natural stone processing companies.

LITERATURE REVIEW

When cement is substituted with marble powder that has been discarded, the compressive strength of concrete cubes is increased. When 10% of the cement weight is replaced with waste marble powder, there is no decrease in the split tensile strength of the cylinders; however, once this threshold is exceeded, there is a decrease. Both tensile and compressive strengths are at their peak when waste marble powder accounts for 12% of the cement in a mixture. The ideal ratio of cement to marble powder replacement for cubes and cylinders is 12% cement to marble powder. "The Effect of Marble Powder Having a High Lime Content on the Production of High Strength Concrete" (2013). Volume 8, Issue 4, April 2013 ISSN 1819-6608. Increasing the amount of lime that is added to the marble powder in the concrete was tried. We investigated the longevity of concrete used in demolition projects that contained up to 10% marble powder. Table 1 lists the cement properties. The amount of marble powder in the replacement had an effect on the material's flexural, splitting, and compressive strengths. Table 2 shows the fine aggregate physical properties and Table 3 presents the fine aggregate. The physicochemical properties of fine aggregate when compared to conventional concrete are discussed. An addition of 10% marble powder as a replacement for cement resulted in an increase in compressive strength of 46.80 MPa at 7 days and an improvement in mechanical properties. Evaluation was done using a fine aggregate sieve.

MATERIAL USED

For the purpose of this research, Portland cement, fine and coarse aggregate made of cement, marble dust, tyre fibre, and a combination of all of these components were utilized. The making of concrete requires each of these individual components in order to succeed.

Table 1. Cement Characteristics Properties

S.N.	Specified value as per IS:8112-1989	Characteristics
1.	>30	Initial setting time (minutes)
2.	<600	Final setting time (minutes)
3.	3.15	Specific gravity

4.	10	Soundness (mm)
5.	 >33 >43	Compressive strength (N/mm^2) (i) 7 days (ii) 28 days
6.	30	Consistency of cement (%)
7.	10	Fineness of cement (gm)

Table 2. Fine Aggregate Physical Properties

Specified Value as per ISO:383-1970	Physical Properties
2%	Free moisture content
1.82%	Water absorption
2.60	Specific gravity of fine aggregate

Table 3. Fine Aggregate

S.N.	IS Sieve Designation	IS:383-1970 requirements for zone-II
1	150 µm	0–10
2	300 µm	8–30
3	600 µm	35–55
4	1.18 mm	55–90
5	2.36 mm	75–100
6	4.75 mm	90–100

ANALYSIS of RESULTS

Compressive Strength

After analysing the 7-day and 28-day results of tyre fibre reinforced concrete, optimal ratio of cement replacement was determined to be 0.2% (Table 4). Figure 1 depicts the compressive strength of concrete with 0.2% marble dust and tyre fibre.

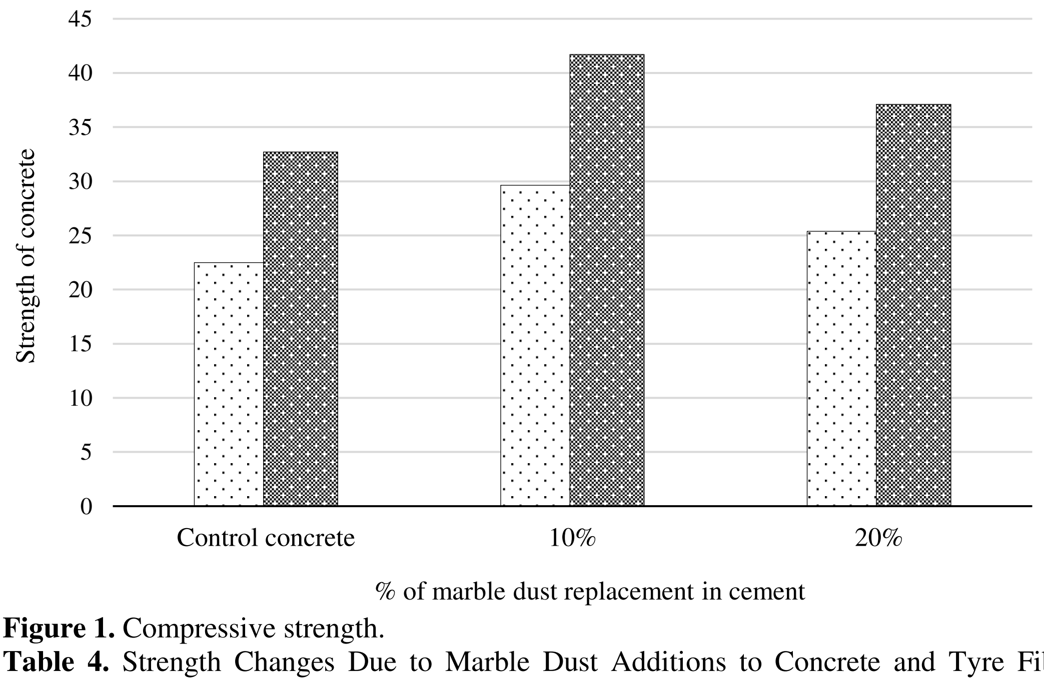

Figure 1. Compressive strength.

Table 4. Strength Changes Due to Marble Dust Additions to Concrete and Tyre Fiber Additions (0.2% Total)

S.N.	No. of Days	% Marble dust Replacement in Cement		
		Control Concrete	10%	20%
1	7	22.52	29.68	25.67
2	28	32.82	41.80	37.20

Split Tensile Strength

After analyzing the 7-day and 28-day results of tyre fiber reinforced concrete, the optimal ratio of cement replacement was determined to be 0.2% (Table 5). Figure 2 shows the variation of split tensile strength for 0.2% tyre fiber and marble dust.

Table 5. Comparison of the tensile strength of mixtures containing 0.2% tyre fibre and varying amounts of marble dust

S.N.	No. of Days	% Marble Dust Replacement in Cement		
		Control Concrete	10%	20%
1	7	2.16	2.96	2.51
2	28	3.12	4.12	3.64

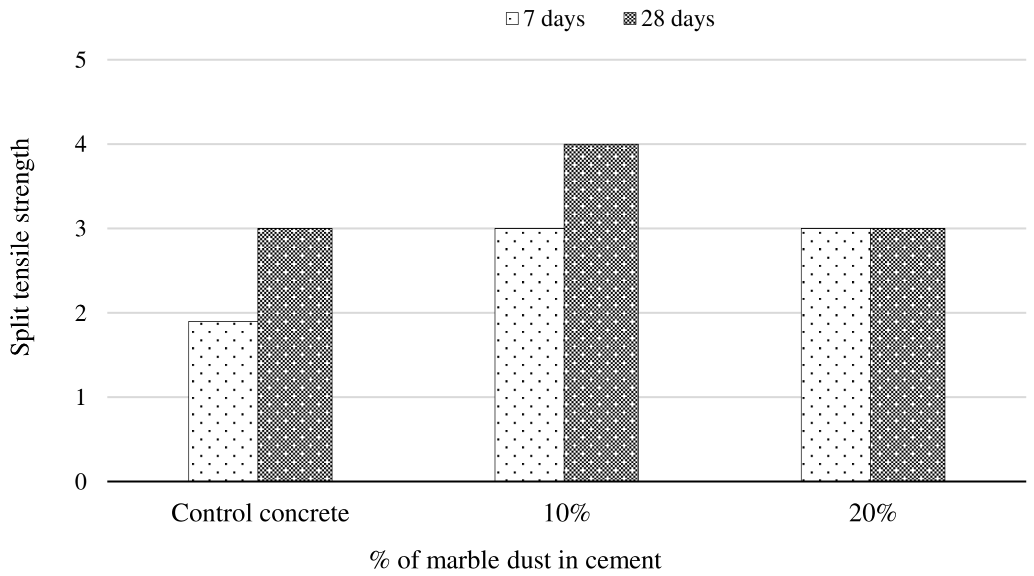

Figure 2. Variation of split tensile strength.

DISCUSSION OF TEST RESULTS

A. Increasing the amount of tyre fibre added to concrete raises its compressive strength.
B. When more tyre fibre was added, split tensile strength also enhanced.
C. Addition of tyre fibre increased the concrete's flexural strength, but only up to a particular proportion.
D. Marble dust may be used as replacement for cement, and as percentage of replacement rises, the concrete's weight decreases.
E. Adding 0.2% of tyre fibre and 20% of cement with marble powder produced the best results.

CONCLUSION BASED ON TEST RESULTS

After the concrete was poured, it was realized that by increasing the amount of tyre fibre in the mix by just 2%, the concrete's compressive and tensile strengths would be greatly enhanced. This problem was only uncovered after it was far too late to pour the concrete. A series of tests revealed that the concrete with 20% marble dust and 0.2% tyre fibre had the highest compressive strength and the highest split tensile strength.

When the suggested amount of tyre fibre is added to concrete, the material gains a 16.08% increase in compressive strength and a 32.05% increase in split tensile strength. Since no tyre fibres were found in either this or the control concrete, they can be considered equivalent. The compressive strength and split tensile strength of concrete containing the optimal proportions of tyre fibre and marble dust were significantly higher than that of concrete made using the control mixture. This held true for the concrete's compressive strength as well as its split tensile strength.

REFERENCES

1. Sakalkale AD, Dhawale GD, Kedar RS. Experimental study on use of waste marble dust in concrete. Int J Eng Res Appl. 2014; 4 (10): 44–50.
2. Ahmad J, Zhou Z, Majdi A, Alqurashi M, Deifalla AF. Overview of concrete performance made with waste rubber tires: a step toward sustainable concrete. Materials (Basel). 2022; 15 (16): 5518.
3. Kuoribo E, Mahmoud H. Utilisation of waste marble dust in concrete production: a scientometric review and future research directions. J Cleaner Prod. 2022; 374: 133872.
4. Sharma A, Chaturvedi R, Sharma K, Saraswat M. Force evaluation and machining parameter optimization in milling of aluminium burr composite based on response surface method. Adv Mater Process Technol. 2022; 8 (4): 4073–4094.
5. Zamora-Castro SA, Salgado-Estrada R, Sandoval-Herazo LC, Melendez-Armenta RA, Manzano-Huerta E, Yelmi-Carrillo E, Herrera-May AL. Sustainable development of concrete through aggregates and innovative materials: a review. Appl Sci. 2021; 11 (2): 629.
6. Gayana BC, Ram Chandar K. Sustainable use of mine waste and tailings with suitable admixture as aggregates in concrete pavements – a review. Adv Concrete Construct. 2018; 6 (3): 221–243.
7. Dabbaghi F, Rashidi M, Nehdi ML, Sadeghi H, Karimaei M, Rasekh H, Qaderi F. Experimental and informational modeling study on flexural strength of eco-friendly concrete incorporating coal waste. Sustainability. 2021; 13 (13): 7506.
8. Chaturvedi R, Islam A, Sharma K. A review on the applications of PCM in thermal storage of solar energy. Mater Today Proc. 2021; 43: 293–297.
9. Ahmad J, Majdi A, Babeker Elhag A, Deifalla AF, Soomro M, Isleem HF, Qaidi S. A step towards sustainable concrete with substitution of plastic waste in concrete: overview on mechanical, durability and microstructure analysis. Crystals. 2022; 12 (7): 944.
10. Abbas S, Ahmed A, Waheed A, Abbass W, Yousaf M, Shaukat S, Alabduljabbar H, Awad YA. Recycled untreated rubber waste for controlling the alkali–silica reaction in concrete. Materials. 2022; 15 (10): 3584.
11. Kumar A, Sharma K, Dixit AR. A review of the mechanical and thermal properties of graphene and its hybrid polymer nanocomposites for structural applications. J Mater Sci. 2019; 54 (8): 5992–6026.
12. Nayak SK, Satapathy A. Development and characterization of polymer-based composites filled with micro-sized waste marble dust. Polym Polym Composites. 2021; 29 (5): 497–508.
13. Singh PK, Sharma K. Mechanical and viscoelastic properties of in-situ amine functionalized multiple layer graphene/epoxy nanocomposites. Curr Nanosci. 2018; 14 (3): 252–262.
14. Nitisha S, Kumar R. Review on use of waste marble powder as partial replacement in concrete mix. Int J Eng Res Technol. 2015; 4 (5): 501–504.
15. Kumar A, Sharma K, Dixit AR. A review on the mechanical properties of polymer composites reinforced by carbon nanotubes and graphene. Carbon Lett. 2021; 31 (2): 149–165.

